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(71)(72) Applicant and Inventor: McCARTHY, John, Patrick [AU/AU]; 261 Moon's Lane, Brookfield, QLD 4350 (AU).

(74) Agent: PIZZEY, John, Kingston; PO Box 1374, Brisbane, QLD 4001 (AU).

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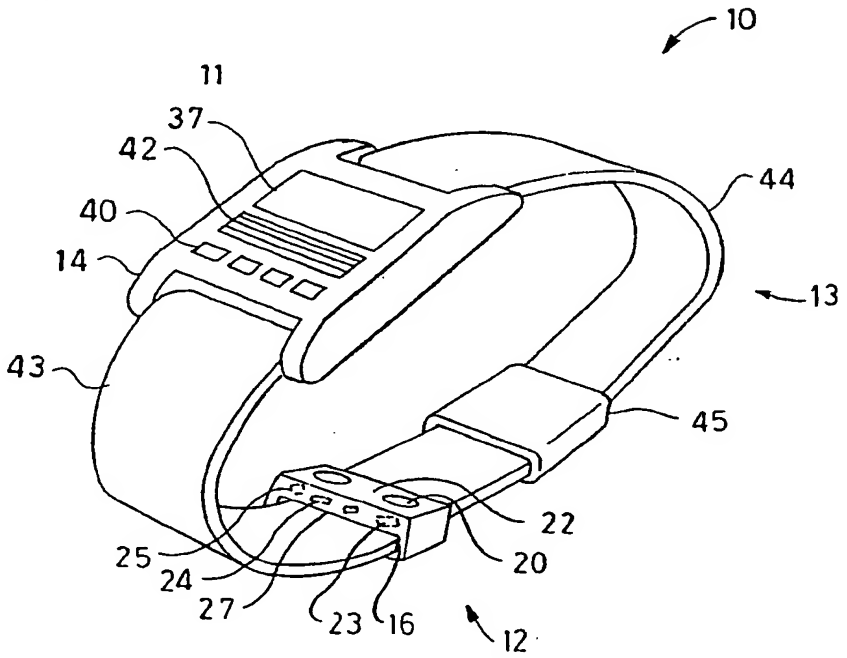
(54) Title: MONITORING APPARATUS



(57) Abstract

An apparatus for monitoring one or more human physiological functions such as pulse rate, body temperature and body hydration levels is disclosed. In particular, a pulse monitoring apparatus is disclosed which is incorporated in a wristwatch (10). The apparatus comprises an ultrasonic transducer assembly (12) which measures blood velocity in the radial artery utilising the doppler effect and provides output signals which are processed by processing circuitry (35) to give an output which is utilised to indicate the pulse rate on a watch display (37) in place of or in addition to a time display. The ultrasonic transducer assembly (12) is attached to the wrist band (13), and is moveable along the latter relative to the indicating assembly (11) for accommodating wrists of differing size.

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"MONITORING APPARATUS"

-- BACKGROUND OF THE INVENTION --

This invention relates to monitoring apparatus. This invention has particular application to the monitoring of human physiological functions, and for illustrative purposes, reference will be made to such application. However, it is to be understood that this invention may be used for other applications, such as the monitoring of animals.

The level of stress to which a human body is being subjected can be monitored by measuring physiological functions such as pulse rate, body temperature and body hydration. Measurement of these variables during exercise is highly desirable. For exercise to be most beneficial, the heart rate must be elevated above a value of sixty percent of the maximum recommended rate, while exercise which elevates the heart rate above the maximum recommended rate depending on age and fitness can lead to serious effects.

Measurement of body hydration is also very important to athletes, as it can provide an early warning of dehydration of the body. Temperature measurement, with or without other parameter measurements, may be used for the detection of hypothermia or hyperthermia in a wearer. An increase in heart rate may also warn of hypothermia or hyperthermia.

Continuous monitoring of physiological parameters is also desirable for persons with a history of heart disease, or persons recovering from cardiac surgery.

-- DESCRIPTION OF THE PRIOR ART --

Hitherto, continuous heart rate monitoring of athletes

and the like has only been possible by attaching electrocardiogram sensors to a harness worn about the chest, a fixed console or wrist-mounted monitoring device being wired to the sensors to measure the heart rate. Alternatively, a sensor sleeve may be worn over a finger, using optical sensors which respond to the change in light transmission through the finger during a pulse cycle. Both of these devices are inconvenient to fit and uncomfortable in use, and consequently have met with limited commercial success.

The present invention aims to alleviate these and other disadvantages and to provide monitoring apparatus which will be reliable and efficient in use. With the foregoing and other objects in mind, this invention in one aspect resides in monitoring apparatus for monitoring a desired physiological function, said monitoring apparatus including:-

sensing means for sensing the desired physiological function, said sensing means being detachably attachable to the body of a user;

retaining means for retaining said sensing means adjacent a selected portion of the body of a user;

signal processing means for processing the output from said sensing means; and

indicating means for providing a sensible output which is variable in accordance with changes in the output from said sensing means.

Preferably, the physiological function is pulse rate, and the sensing means is in the form of a pulse rate sensor. Of course, if desired, other physiological functions such as body temperature or body hydration level may be measured, and suitable sensing means such as thermometers, including laser thermometers, or skin resistivity measurement means respectively may be used.

The pulse rate sensor may take any desired form. For instance, dimensional changes in the body as a result of the

dilation of an artery during the pulse cycle may be monitored by displacement sensing means, such as by a strain gauge, or pressure sensing means of any suitable form supported against the artery. It is preferred, however, that the pulse rate sensor be in the form of an ultrasonic transducer assembly disposed in such relationship to an artery or the like whereby changes in the rate of flow of blood or velocity during a pulse cycle may be sensed by doppler effect or by other sensible effects resulting from changes in the rate of blood flow, such as variations in arterial noise levels or size. The ultrasonic transducer assembly may include piezoelectric or piezoceramic transducers, or any other desired ultrasonic transducers.

The indicating means may be formed in any desired configuration, and may include visual indication means, providing a visual display related to the output of the sensing means, and alarm means for indicating visually, audibly, or by tactile feedback, e.g. for underwater use, that the output from the sensing means has reached, or passed, a preset limit. The visual indication means may be in any desired form such as an analog readout, but it is preferred that it be in the form of a digital display whereby existing digital watch technology may be utilised. Alternatively, a visual display unit (VDU) may be utilised for the indicating means.

The alarm means may take any desired form, such as a flashing light. However, it is preferred that the alarm means be in the form of an audible alarm such as a buzzer, or a tactile alarm such as electrical signal generation means or the like producing signals applied to the skin, whereby a wearer may be made aware of an alarm condition while engaged in activity which does not permit the indicating means to be constantly observed.

The retaining means may be in the form of a harness of adjustable length and may hold the sensing means adjacent any

desired portion of a user's body. Suitably, the sensing means is held adjacent the wrist of a user and in close proximity to the radial artery therein, and the retaining means is in the form of a wristband which may also support the signal processing means and the indicating means. The signal processing and the indicating means may be enclosed in a housing for their protection, and the housing may also enclose a timer or watch. If desired, the signal processing means, the indicating means and the timer may be integrated into an assembly such that it may be worn as a convenient alternative to a wrist watch. Alternatively, for use on an animal such as a racehorse, the sensor means may be held adjacent a portion of the animal, such as an artery, and the indicating means may be placed in a position convenient for viewing by a rider. If desired, telemetering means may be provided such that the indicating means may be placed remote from the sensing means, such as beside a racetrack or an exercise facility.

The sensing means may be formed as a sensing assembly adjustably mountable relative to the housing along the wristband whereby the sensing assembly and the housing may be positionable in a desired spaced relationship around the wrists of users of differing size, such as with the housing adjacent the dorsal portion of the wrist and the sensing assembly adjacent the radial artery. The wristband may include a flexible element such as an elastic section whereby the sensing assembly may be urged against the wrist of a user.

Suitably, the sensing means may be of size and shape such that it may fit snugly between the radius bone and the tendons on the ventral aspect of a user's wrist, whereby movement of the sensing means relative to the radial artery in response to operation of the tendons may be minimised. If desired, the sensing means may be spring biassed into contact with the wrist such that it may maintain firm contact with

the skin of the ventral aspect of the wrist during movement of the wrist.

The retaining means may include transmission straps which include electrical connectors such as wires disposed therealong for coupling the sensing means and the indicating means. The electrical connectors may be in the form of exposed conductor tracks which are contacted by pickups attached to the sensing means or the housing. It is preferred, however, that the electrical connectors be formed as reactive elements such as inductors or capacitors and that co-operating reactive elements be provided associated with the sensing means or the housing such that an electrical circuit may be completed between the sensing means and the housing without the use of exposed electrical conductors. Suitably, a transmission strap may be provided with a pair of flat-coiled inductors, and the co-operating reactive elements may be in the form of inductive coils such that transmission of data and power may be effected by inductive means. Magnetic cores formed from materials such as ferrite may be associated with the flat-coiled inductors and/or the co-operating reactive elements for enhancing the transfer of data and power.

The signal processing means may include frequency-dependent filtering whereby the entry of extraneous noise which occurs at frequencies differing from the desired pulse rate signals into the pulse-counting circuitry may be minimised. If desired, more complex signal processing means may be utilised, including fourier analysis or auto-correlation such that false pulse registration due to extraneous noise occurring within the frequency band of the desired pulse rate may be minimised. Noise-cancelling circuitry may also include an accelerometer, and the output from the accelerometer may be processed along with the signal from the sensing means whereby noise emanating from the sensing means as a result of mechanical shock may be

substantially neutralised.

The signal processing means may include digital signal processing techniques such as pulse position prediction, limiting rate-of-change of pulse rate. Other techniques for separating valid pulse cycles from extraneous noise may include recognition means for recognising characteristic portions of a pulse cycle, such as the dicrotic notch, the shape of the pulse peak, the rate of rise or fall of the signal, or the width of the base of the pulse signal. The signal processing means may be disposed for adaptive alteration of the signal processing technique according to the pulse rate and the relative magnitude of the pulse rate and noise signals.

In another aspect of this invention, multi-purpose monitoring apparatus is provided including a plurality of sensing means associated with the monitoring of respective physiological functions whereby the indicating means may be utilised for the monitoring of said respective physiological functions. Suitably, the multi purpose monitoring apparatus may include, but is not limited to, sensing means for pulse rate determination, body temperature measurement, and body dehydration state.

In a further aspect, this invention resides in a method of monitoring a desired physiological function, including:-

providing monitoring apparatus of the type having sensing means for sensing the desired physiological function, said sensing means being detachably attachable to the body of a user,

retaining means for retaining said sensing means adjacent a selected portion of the body of a user, signal processing means for processing the output from said sensing means, and indicating means for providing a sensible output which is variable in accordance with changes in the output from said sensing means;

attaching said sensing means to the body of a user; and

operating said monitoring apparatus such that the desired physiological function is monitored.

-- BRIEF DESCRIPTION OF THE DRAWINGS --

In order that this invention may be more easily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention, wherein:-

FIG. 1 is a monitoring assembly according to the invention;

FIG. 2 is a cross-sectional view of the monitoring assembly shown in FIG. 1;

FIG. 3 is a developed view of the monitoring assembly shown in FIG. 1;

FIG. 4 is a block diagram of the monitoring assembly, and

FIG. 5 shows an alternative monitoring assembly display.

-- DESCRIPTION OF THE PREFERRED EMBODIMENTS --

The monitoring assembly 10 illustrated in FIGS. 1, 2, 3 and 4 comprises an indicating assembly 11 and a sensing assembly 12 which are mounted along a flexible wristband 13. The indicating assembly 11 has a housing 14 in the form of a wristwatch casing, and the wristband 13 passes through mounting slots 15 at the ends of the housing 14, and the wristband 13 passes through an adjustment slot 16 on the rear face of the sensing assembly 12.

The sensing assembly 12 contains a transmitting ultrasonic transducer element 20 and a receiving ultrasonic transducer element 21 mounted with their sensing axes coinciding at a point above the front face 22 of the sensing assembly 12. The transmitting transducer element 20 is connected to a power pickup coil 23, while the receiving

ultrasonic transducer element 21 is connected to a data coil 24 through a buffer amplifier 25. Power to operate the latter is provided from the power pickup coil 23 through a rectifier assembly 26. The coils 23 and 24 are mounted adjacent the rear face 27 of the sensing assembly 12.

The housing 14 contains a battery 30, which powers an oscillator 31, the output of which is connected to a power driver coil 32 mounted adjacent the housing rear face 33. A housing pickup coil 34 is also mounted adjacent the rear face 33, and is connected to amplification and signal processing circuitry 35. The output from the latter is passed to the timing module 36 which processes it, producing an output which is displayed on the display 37 by programming the display by means of the keys 40. Alternatively, the display 37 may be programmed to display the time, as generated by a watch module 41. A beeper 42 is fitted to the housing 14 and may be programmed by the timing module 36 to sound an alarm for a particular signal condition in the output of the housing pickup coil 34.

The wristband 13 has a semi-rigid section 43 and an elastic section 44, and the latter may be stretched to tension the wristband 13. A buckle assembly 45 is attached to the end of the semi-rigid section 43 opposite the elastic section 44. A pair of flat coil assemblies 46 and 47 are embedded within the semi-rigid section 43.

The monitoring assembly 10 is prepared for use by buckling it around a wearer's wrist 50 and sliding the housing 14 and the sensing assembly 12 along the wristband 13 to position the housing 14 on the dorsal portion 51 of the wrist 50 and the sensing assembly 12 adjacent to the radial artery 52. When the monitoring assembly 10 is energised, power is transferred to the power driver coil 32 by the oscillator 31, and is passed along the flat coil 47 to the power pickup coil 23 and thence to the transmitting ultrasonic transducer 20. The ultrasonic pulse train

generated by the latter passes through the skin and the wall of the radial artery 52. Some of the ultrasonic energy is reflected from the blood flowing within the radial artery 52 and is received by the receiving transducer element 21. The electrical output from the latter is amplified by the buffer amplifier 25 and passed through the data coil, the flat coil assembly 46 and the housing pickup coil 34 to the processing circuitry 35, where the signal is amplified and pulse rate data is extracted from it. This data is passed to the timing module, which converts this data into a heartbeats-per-minute signal which is passed to the display 37 for display to the user. The timing module 36 also controls the beeper 42, sounding an alarm if the heartbeats-per-minute increases above or decreases below pre-programmed limits.

The display 60 shown in FIG. 5 includes a large central display 61 of the measured pulse rate in an illuminated colour, e.g. red for dark visibility, and is adapted to flash in an alarm mode. An upper alarm rate setting display 62 in a different illuminated colour, e.g. blue, is located above the central display 61, while a lower alarm rate setting display 63 in a similar illuminated colour is located below it. An upper "alarm on" display 64 and a lower "alarm on" display 65 are located adjacent upper and lower alarm rate displays 62 and 63 respectively and are energised to indicate that the alarm limits have been set. A pulse detection light 66 for testing the operation of the sensor assembly 12 is positioned to the right of the central display 61.

Push buttons (not shown) are provided for performing the following functions:-

(i) Mode Change

(a) High Alarm (flashing display 61)

(b) Low Alarm (flashing display 61)

(c) Pulse Rate Alarm Test (flashing display 61)

(d) Pulse Rate Measurement (Operating Mode non-flashing display 61)

(ii) Setting Change

For all modes except (d) above a single press on this button increases reading by one. If the button is depressed for three seconds the numbers run through quickly (zero to two hundred and fifty) to reach the desired setting.

(a) High Alarm - Display 61 stops flashing and is set when (i) is changed to another mode.

(b) Low Alarm - As above

(c) After alarms are set and in "on" position, running the monitoring assembly 10 through its measuring range for testing will elicit alarm functions similar to operating mode, i.e., alarm sounds at rates below "low" setting and above "high" setting.

After the display 61 reaches two hundred and fifty beats per minute it returns to zero and recommences the run-through. This applies also to alarm settings.

(iii) Alarm on/off

For "High" and "Low" alarms separately.

(iv) Pulse detection test mode

A flashing light, (e.g. green), flashes in time with the pulse. This rate can be compared with heart rate by feeling the pulse in the opposite wrist. This enables a check on correct positioning of the transducer.

(v) Unit on/off switch

To conserve power when unit not in use.

The number of buttons may be reduced multiplexing functions, e.g. - eliciting some functions by pressing two adjacent buttons simultaneously.

It may be desirable for the flashing light synchronised with the pulse to operate continuously, to enable rough checks on accuracy during exercise, but operation of the light may be made optional for conserving battery power.

The audible alarm is synchronised with the pulse rate, enabling the wearer to monitor rate of increase or decrease of pulse rate aurally. In addition, as a too high pulse rate

suggests danger, a faster beep will suggest urgency.

The different rates of beep may be sufficient to distinguish high and low alarms, but different tones for the two may also be used.

It will of course be realised that while the above has been given by way of illustrative example of this invention, all such and other modifications and variations thereto as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of this invention as is herein set forth.

-- CLAIMS --

1. Monitoring apparatus for monitoring a desired physiological function, said monitoring apparatus including:-
sensing means for sensing the desired physiological function, said sensing means being detachably attachable to the body of a user;
retaining means for retaining said sensing means adjacent a selected portion of the body of a user;
signal processing means for processing the output from said sensing means; and
indicating means for providing a sensible output which is variable in accordance with changes in the output from said sensing means.

2. Monitoring apparatus as defined in Claim 1, wherein said physiological function is pulse rate, and said sensing means includes a pulse rate sensor.

3. Monitoring apparatus as defined in Claim 2, wherein said pulse rate sensor includes an ultrasonic transducer assembly disposed in relationship to an artery or the like whereby changes in the rate of flow of blood during a pulse cycle may be sensed by doppler effect.

4. Monitoring apparatus as defined in Claim 1, wherein said indicating means includes a visual display related to the output of the sensing means.

5. Monitoring apparatus as defined in Claim 1, wherein said indicating means includes alarm means for indicating visually, audibly, or by tactile feedback that the output from the sensing means has reached or passed a preset limit.

6. Monitoring apparatus as defined in Claim 4, wherein

said indicating means and said signal processing means are included within a time-keeping watch.

7. Monitoring apparatus as defined in Claim 4, wherein said indicating means and said signal processing means are included within a display console.

8. Monitoring apparatus as defined in Claim 7, wherein said display console comprises a computer, and said signal processing means includes software-programmable digital signal analysis.

9. Monitoring apparatus as defined in Claim 1, wherein said retaining means includes a sensor harness of adjustable length for holding said sensing means adjacent a selected portion of a user's body.

10. Monitoring apparatus as defined in Claim 1, wherein said sensor harness includes a wrist strap for holding said sensor adjacent the radial artery of a user.

11. Monitoring apparatus as defined in Claim 10, wherein said wrist strap supports said signal processing means and said indicating means.

12. Monitoring apparatus as defined in Claim 11, wherein said signal processing, said indicating means and a time-keeping watch movement are enclosed in a protective housing.

13. Monitoring apparatus as defined in Claim 12, wherein said sensing means includes a sensing assembly adjustably mountable relative to said protective housing along said wristband.

14. Monitoring apparatus as defined in Claim 13, wherein

said wrist strap includes an electrical transmission element for maintaining operative contact between said sensing assembly and said protective housing.

15. Monitoring apparatus as defined in Claim 14, wherein said electrical transmission element includes reactive electrical elements.

16. Monitoring apparatus as defined in Claim 1, wherein said signal processing means includes frequency-dependent filtering apparatus.

17. Monitoring apparatus as defined in Claim 1, wherein said signal processing means includes auto-correlation apparatus.

18. Multi-function monitoring apparatus for monitoring a plurality of desired physiological functions, said monitoring apparatus including:-
a plurality of sensing means for sensing the desired physiological functions, said sensing means being detachably attachable to the body of a user;
retaining means for retaining said sensing means adjacent a selected portion of the body of a user;
signal processing means for processing the output from said sensing means; and
indicating means for providing a sensible output which is variable in accordance with changes in the output from said sensing means.

19. Multi-function monitoring apparatus as defined in Claim 18, wherein said sensing means include pulse sensing means, body temperature sensing means, and body dehydration state.

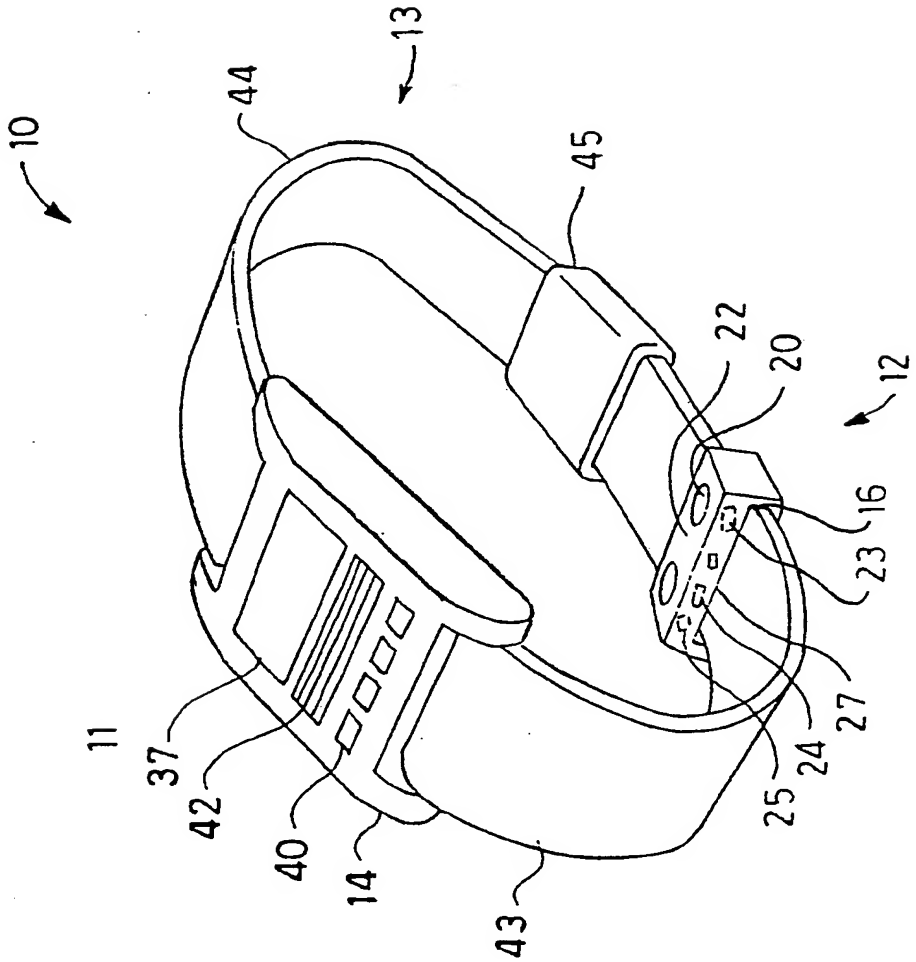

FIG. 1

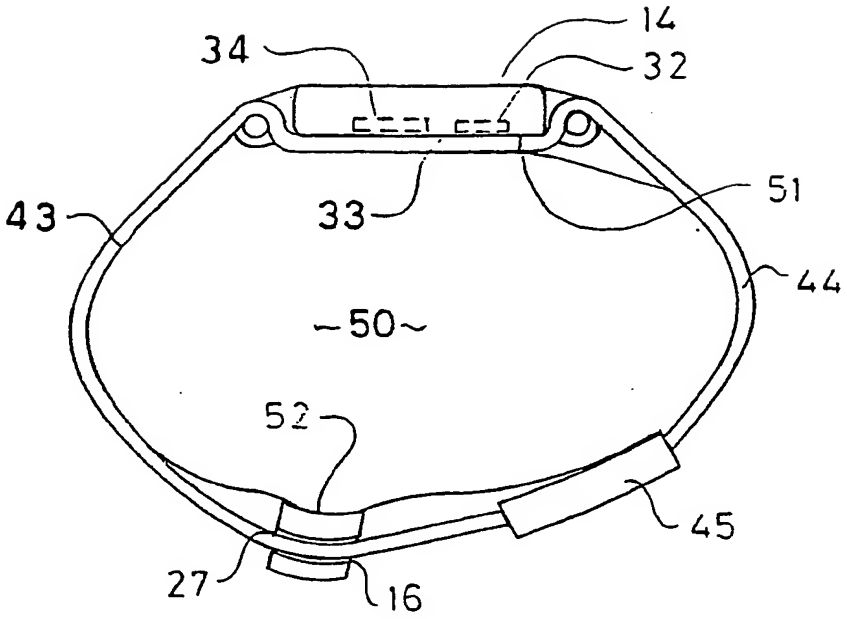

FIG. 2

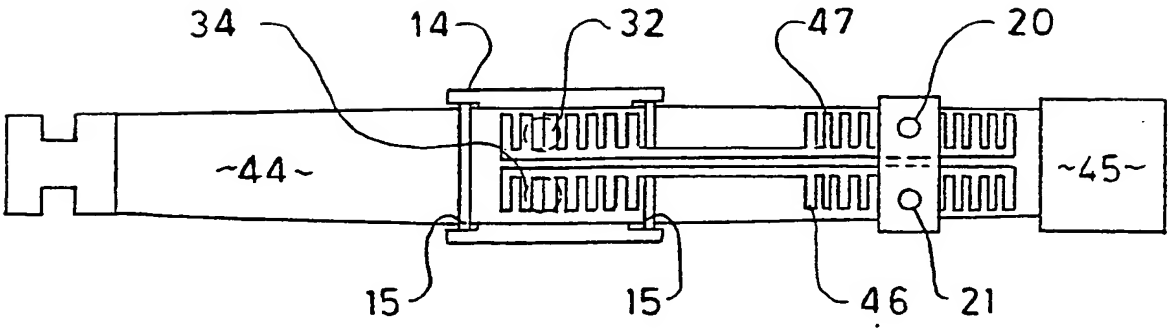

FIG. 3

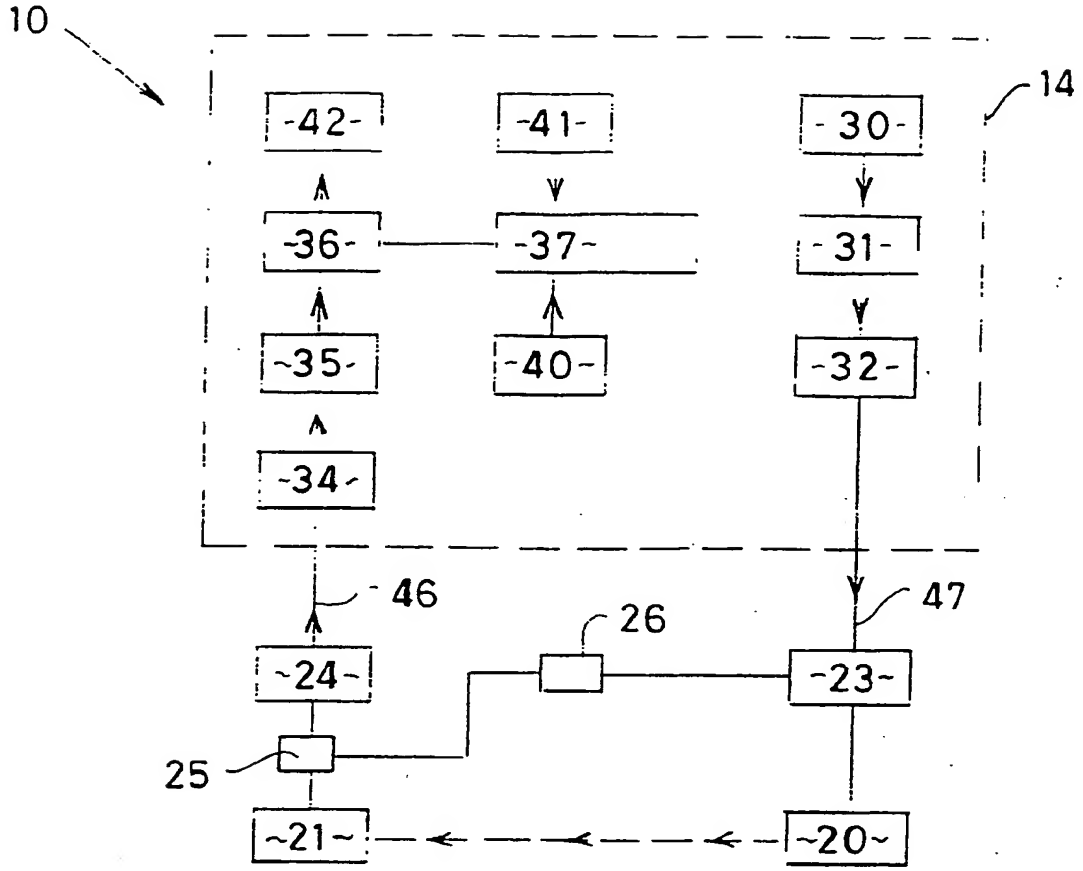

FIG. 4

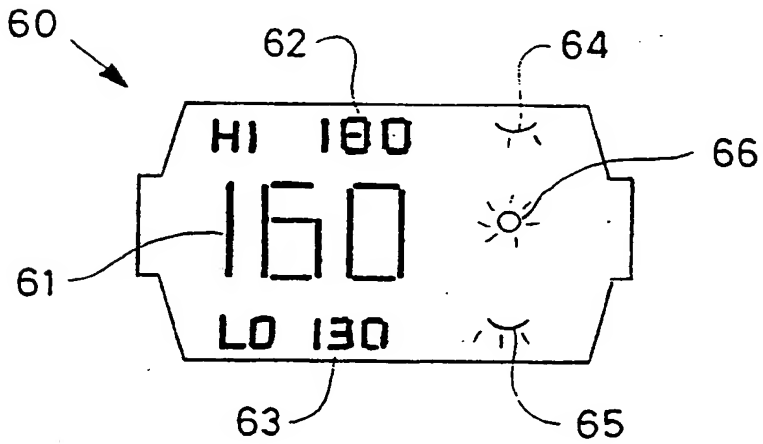

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 89/00283

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] A61B 5/02, 5/00

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	A61B 5/02, 5/00, 8/02, 8/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above, Australian Classification 87.4

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	GB,A, 1348154 (NATIONAL RESEARCH DEVELOPMENT CORP) 13 March 1974 (13.03.74)	(1-4,16,18)
X	DE,A, 3345739 (FRAINHOFER-GES FORD ANGE) 4 July 1985 (04.07.85)	(1-4,10-14,16)
X,Y	US,A, 4086916 (FREEMAN et al) 2 May 1978 (02.05.78)	(1-6,10-13,14)
X,Y	FR,A, 2498921 (LABOURGADE & DACHERT) 6 August 1982 (06.08.82)	(1-6,10-13,14)
X	US,A, 4397317 (VILLA-REAL) 9 August 1983 (09.08.83)	(1,2,4,5,7,8,18)
X	US,A, 4367752 (JIMENEZ et al) 11 January 1983 (11.01.83)	(1,2,4,7-9,16,18)
X	US,A, 4202350 (WALTON) 13 May 1980 (13.05.80)	(1,2,4,6,10-15,18)
X,Y	AU,B, 27861/77 (510831) (MEDTRONIC, INC.) 8 MARCH 1979 (08.03.79)	(1,2,4,6,10-12,16, 18,19)
X,Y	US,A, 4450843 (BARNEY et al) 29 May 1984 (29.05.84)	(1,2,4,6,10-12,16, 18,19)
X	MACHINE DESIGN, Volume 53, no.4, issued 1981, February 26. Wristwatch computer monitors joggers pulse. See page 12.	(1,2,4,5,10-12,18)

* Special categories of cited documents: 10

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
28 September 1989 (28.09.89)	10 October 1989
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	A.W. DUKE a.W. Duke

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 89/00283

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Patent Document Cited in Search Report	Patent Family Members			
US 4367752	US 4434801			
AU 27861/77	CA 1088634	CH 615582	DE 2736751	
	FR 2361857	GB 1579690	JP 53023183	
	SE 7709186	US 4295472		

END OF ANNEX